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APPLICATION FOR LETTERS PATENT

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A BATTERY POWERABLE APPARATUS, RADIO FREQUENCY COMMUNICATION DEVICE, AND ELECTRIC CIRCUIT

Thin Profile Battery Bonding Method, Method Of  
Conductively Interconnecting Electronic Components,  
Battery Powerable Apparatus, Radio Frequency  
Communication Device, And Electric Circuit

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INVENTOR

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1 ~~Thin Profile Battery Bonding Method, Method Of Conductively~~  
2 ~~Interconnecting Electronic Components, A Battery Powerable Apparatus,~~  
3 ~~Radio Frequency Communication Device, And Electric Circuit~~

4 *b*  
5 *Inv. H*

6 **TECHNICAL FIELD**

7 This invention relates to thin profile battery bonding methods, to  
8 methods of conductively interconnecting electronic components, to battery  
9 powerable apparatus, to radio frequency communication devices, and to  
10 electric circuits.

11 **BACKGROUND OF THE INVENTION**

12 Thin profile batteries comprise batteries that have thickness  
13 dimensions which are less than a maximum linear dimension of its  
14 anode or cathode. One type of thin profile battery is a button type  
15 battery. Such batteries, because of their compact size, permit electronic  
16 devices to be built which are very small or compact.

17 One mechanism by which thin profile batteries are electrically  
18 connected with other circuits or components is with electrically  
19 conductive adhesive, such as epoxy. Yet in some applications, a suitably  
20 conductive bond or interconnection is not created in spite of the highly  
21 conductive nature of the conductive epoxy, the outer battery surface,  
22 and the substrate surface to which the battery is being connected. This  
23 invention arose out of concerns associated with providing improved  
24 conductive adhesive interconnections between thin profile batteries and

1 conductive nodes formed on substrate surfaces. The invention has other  
2 applicability as will be appreciated by the artisan, with the invention  
3 only being limited by the accompanying claims appropriately interpreted  
4 in accordance with the Doctrine of Equivalents.

5

6 SUMMARY OF THE INVENTION

7 The invention in one aspect includes a thin profile battery  
8 bonding method. In one implementation, a curable adhesive composition  
9 is provided which comprises an epoxy terminated silane. A thin profile  
10 battery and a substrate to which the thin profile battery is to be  
11 conductively connected are also provided. The curable adhesive  
12 composition is interposed between the thin profile battery and the  
13 substrate. It is cured into an electrically conductive bond electrically  
14 interconnecting the battery and the substrate.

15 The invention in another aspect includes a method of conductively  
16 interconnecting electronic components. In one implementation, a curable  
17 adhesive composition comprising an epoxy terminated silane is provided.  
18 First and second electronic components to be conductively connected  
19 with one another are provided. The curable adhesive composition is  
20 interposed between the first and second electronic components. The  
21 adhesive is cured into an electrically conductive bond electrically  
22 interconnecting the first and second components.

23 The invention in still another aspect includes interposing a curable  
24 epoxy composition between first and second electrically conductive

1 components to be electrically interconnected. At least one of the  
2 components comprises a metal surface with which the curable epoxy is  
3 to electrically connect. The epoxy is cured into an electrically  
4 conductive bond electrically interconnecting the first and second  
5 components. The epoxy has an effective metal surface wetting  
6 concentration of silane to form a cured electrical interconnection having  
7 a contact resistance through said metal surface of less than or equal to  
8 about 0.3 ohm-cm<sup>2</sup>.

9 The invention in a further aspect includes a battery powerable  
10 apparatus. In one implementation, such includes a substrate having a  
11 surface comprising at least one node location. A thin profile battery  
12 is mounted over the substrate and node location. A conductive  
13 adhesive mass electrically interconnects the thin profile battery with the  
14 node location, with the conductive adhesive mass comprising an epoxy  
15 terminated silane.

16 The invention in still a further aspect includes a radio frequency  
17 communication device. In one implementation, such includes a substrate  
18 having conductive paths including an antenna. At least one integrated  
19 circuit chip is mounted to the substrate and in electrical connection with  
20 a first portion of the substrate conductive paths. A thin profile battery  
21 is conductively bonded with a second portion of the substrate conductive  
22 paths by a conductive adhesive mass, with the conductive adhesive mass  
23 comprising an epoxy terminated silane.

1           The invention in still another aspect includes an electric circuit  
2 comprising first and second electric components electrically connected  
3 with one another through a conductive adhesive mass comprising an  
4 epoxy terminated silane.

5

6 **BRIEF DESCRIPTION OF THE DRAWINGS**

7           Preferred embodiments of the invention are described below with  
8 reference to the following accompanying drawings.

9           Fig. 1 is a side elevational, partial cross sectional, view of a thin  
10 profile battery.

11           Fig. 2 is a side elevational view of a substrate.

12           Fig. 3 is a side elevational view of a battery powerable apparatus.

13           Fig. 4 is a diagrammatic plan view of a radio frequency  
14 communication device.

15

16 **DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS**

17           This disclosure of the invention is submitted in furtherance of the  
18 constitutional purposes of the U.S. Patent Laws "to promote the  
19 progress of science and useful arts" (Article 1, Section 8).

20           Referring to Fig. 1, a single thin-profile battery is indicated  
21 generally with reference numeral 10. In the context of this document,  
22 "thin-profile battery" is intended to define any battery having a thickness  
23 dimension which is less than a maximum linear dimension of its anode  
24 or cathode. The preferred and illustrated battery 10 comprises a

1 circular button-type battery. Such comprises a lid terminal housing  
2 member 14 and a can terminal housing member 12. Can 12 is crimped  
3 about lid 14, having an insulative sealing gasket 16 interposed  
4 therebetween. In the illustrated example, gasket 16 projects outwardly  
5 slightly relative to the crimp as shown.

6 Fig. 2 illustrates a substrate 22 to which thin-profile battery 10  
7 is to be conductively connected. Substrate 22 includes an outer  
8 surface 23 having one node location 24 and another node location 25  
9 to which battery electrical connection is desired. Substrate 22, for  
10 example, can comprise a flexible circuit substrate, wherein nodes 24  
11 and 25 comprise printed thick film ink formed on surface 23.

12 Referring to Fig. 3, a curable adhesive composition or mass 26  
13 comprising an epoxy-terminated silane is interposed between lid 14 of  
14 thin profile battery 10 and substrate 22 over node location 25. Further,  
15 a curable adhesive composition or mass 32 comprising an  
16 epoxy-terminated silane is interposed between can 12 of thin-profile  
17 battery 10 and node location 24 on substrate 22. The preferred  
18 curable adhesive composition comprises a two-part epoxy resin and  
19 hardener system, wherein the preferred epoxy-terminated silane comprises  
20 a glycidoxyl methoxy silane, such as a glycidoxylpropyltrimethoxysilane,  
21 with 3-glycidoxylpropyltrimethoxysilane being a specific example. The  
22 epoxy-terminated silane is preferably present in the curable adhesive  
23 composition at less than or equal to about 2% by weight, with less  
24 than or equal to about 1% by weight being even more preferred.

1       One example 3-glycidoxypyropyltrimethoxysilane is available from  
2       Dow Corning Corporation of Midland, Michigan, as Z-6040<sup>TM</sup> Silane.  
3       An example resin and hardener system for a conductive epoxy is  
4       available from Creative Materials, Inc., of Tyngsboro, MA, as Part  
5       Nos. CMI 116-37A<sup>TM</sup> and CMIB-187<sup>TM</sup>, respectively. In a preferred  
6       example, from 0.5 to 2.0 weight parts of Z-6040<sup>TM</sup> silane is combined  
7       with 100 weight parts of the CMI 116-37A<sup>TM</sup> silver epoxy resin. A  
8       preferred concentration of the Z-6040<sup>TM</sup> is 1 weight part with 100  
9       weight parts of epoxy resin. Such a solution is thoroughly mixed and  
10      combined with, for example, 3 weight parts of the CMIB-187<sup>TM</sup>  
11      hardener, with the resultant mixture being further suitably mixed to form  
12      composition 26.

13      The composition is applied to one or both of battery 10 or  
14      substrate 22, and provided as shown in Fig. 3. An example size for  
15      conductive mass 26 is a substantially circular dot having a diameter of  
16      about 0.080 inch (0.2032 cm) and a thickness of about 0.002 inch  
17      (0.00508 cm). Resistance of a fully cured mass 26 was measured with  
18      an ohmmeter from the top of the mass to the substrate surface, which  
19      comprised a nickel-clad stainless steel Eveready CR2016<sup>TM</sup> button-type  
20      battery can. Typical measured resistance where no epoxy-terminated  
21      silane or other additive was utilized ranged from 10 ohms to 100 ohms,  
22      with in some instances resistance being as high as 1000 ohms. These  
23      correspond to respective calculated contact resistances ranging from  
24      about 0.32 ohm-cm<sup>2</sup> to 3.24 ohms-cm<sup>2</sup>, with as high as 32.43 ohms-cm<sup>2</sup>,

when ignoring the volume resistances of the epoxy mass and substrate. At the time of preparation of this document, 10 ohms (and its associated calculated contact resistance of  $0.32 \text{ ohm-cm}^2$ ) is considered high and unacceptable for purposes and applications of the assignee, such as will be described with reference to Fig. 4. Yet where the epoxy-terminated silane was added, for example at a weight percent of 2% or less, the typical resistance value and range dropped significantly to 0.1 ohm to 1.0 ohm, with 0.2 ohm being typical. These correspond to respective contact resistances of about  $0.0032 \text{ ohm-cm}^2$ ,  $0.032 \text{ ohm-cm}^2$ , and  $0.0064 \text{ ohm-cm}^2$ .

It is perceived that the prior art conductive bonding without the epoxy-terminated silane results from poor wetting characteristics of the conductive epoxy with the metal outer surface of the button-type battery, which typically comprises a nickel-clad stainless steel. The epoxy-terminated silane significantly improves the wetting characteristics relative to the metal surfaces, such as nickel-clad stainless steel, in a conductive epoxy system in a manner which is not understood to have been reported or known in the prior art. Accordingly in accordance with another aspect of the invention, a thin-profile battery bonding method interposes epoxy between a battery and substrate with at least one of such having a metal surface to which the curable epoxy is to electrically connect. The epoxy has an effective metal surface wetting concentration of silane to form a cured electrical interconnection having a contact resistance through said metal surface of less than or equal to

1       about 0.30 ohm-cm<sup>2</sup>. More preferred, the epoxy has an effective metal  
2       surface wetting concentration of silane to form a cured electrical  
3       interconnection have a contact resistance through said metal surface of  
4       less than or equal to about 0.16 ohm-cm<sup>2</sup>. Most preferred, such  
5       concentration provides a contact resistance of less than or equal to  
6       about 0.032 ohm-cm<sup>2</sup>.

7       The curable adhesive composition is then cured into an electrically  
8       conductive bond which electrically interconnects the battery and substrate  
9       as shown in Fig. 3. In the preferred embodiment, such electrically  
10      conductive bond also is the sole physical support and connection of the  
11      battery and its terminals relative to substrate 22.

12      Although the invention was reduced to practice utilizing formation  
13      of a conductive interconnection between a metal battery terminal and  
14      a printed thick film on a substrate, the invention has applicability in  
15      methods and constructions of producing an electric circuit comprising  
16      other first and second electric components which electrically connect with  
17      one another through a conductive adhesive mass comprising, in a  
18      preferred embodiment, an epoxy-terminated silane.

19      Fig. 3 depicts an exemplary battery powerable apparatus and  
20      electric circuit 30 in accordance with an aspect of the invention. In  
21      one preferred implementation, battery powerable apparatus 30 preferably  
22      comprises a radio frequency communication device 50 as exemplified in  
23      Fig. 4. In such example, substrate 22 preferably comprises a flexible  
24      circuit substrate, with nodes 25 and 24 constituting a portion of a series

1 of conductive paths formed of printed thick film ink on surface 23 of  
2 flexible substrate 22. Such conductive paths includes antenna  
3 portions 54. At least one, and preferably only one, integrated circuit  
4 chip 52 is mounted relative to substrate 22 and in electrical connection  
5 with a first portion of the substrate conductive paths. Mounting is  
6 preferably with electrically conductive epoxy such as described above.  
7 Adhesive mass 26 electrically connects lid 14 of thin profile battery 10  
8 with a second portion of the substrate conductive paths. In this  
9 example, such second portion comprises a series of printed thick film  
10 nodes 25. Conductive adhesive mass 32 electrically connects with a  
11 third portion of the substrate conductive paths, which in this example  
12 comprises node 24 in the shape of an arc.

13 An exemplary single integrated circuit chip is described in U.S.  
14 Patent Application Serial No. 08/705,043, which names James O'Toole,  
15 John R. Tuttle, Mark E. Tuttle, Tyler Lowery, Kevin Devereaux, George  
16 Pax, Brian Higgins, Shu-Sun Yu, David Ovard, and Robert Rotzoll as  
17 inventors, which was filed on August 29, 1996, and is assigned to the  
18 assignee of this patent application. The entire assembly 50 preferably  
19 is encapsulated in and comprises an insulative epoxy encapsulant  
20 material. Example constructions and methods for providing the same  
21 are described in a) U.S. Patent Application entitled "Battery Mounting  
22 Apparatuses, Electronic Devices, And Methods Of Forming Electrical  
23 Connections", which names Ross S. Dando, Rickie C. Lake, and Krishna  
24 Kumar as inventors, and was filed on \_\_\_\_\_, and

1       b) U.S. Patent Application entitled "Battery Mounting And Testing  
2       Apparatuses, Methods Of Forming Battery Mounting And Testing  
3       Apparatuses, Battery-Powered Test-Configured Electronic Devices, And  
4       Methods Of Forming Battery-Powered Test-Configured Electronic  
5       Devices", which names Scott T. Trosper as inventor, and which was filed  
6       on \_\_\_\_\_, both of which are assigned to the  
7       assignee of this patent application. Each of the above three referenced  
8       patent applications is fully incorporated herein by reference. Although  
9       this disclosure shows a single battery 10 mounted to substrate 22 for  
10      clarity and ease of description, multiple button type batteries stacked in  
11      series are preferably utilized as is collectively disclosed in the  
12      incorporated disclosures.

13      In compliance with the statute, the invention has been described  
14      in language more or less specific as to structural and methodical  
15      features. It is to be understood, however, that the invention is not  
16      limited to the specific features shown and described, since the means  
17      herein disclosed comprise preferred forms of putting the invention into  
18      effect. The invention is, therefore, claimed in any of its forms or  
19      modifications within the proper scope of the appended claims  
20      appropriately interpreted in accordance with the doctrine of equivalents.